

Severe weather in Greece
Rainfall comparison
Analysis differences
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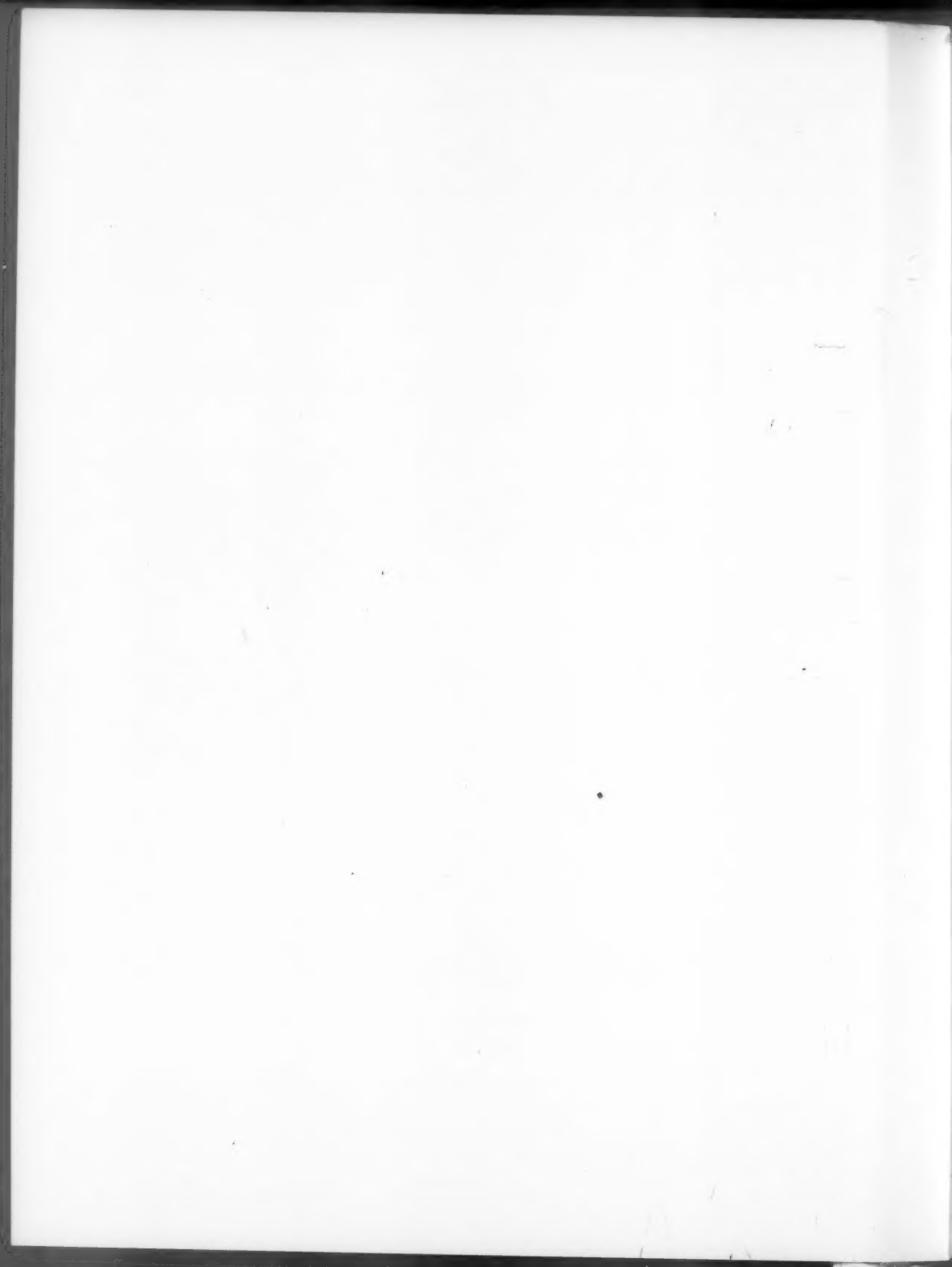
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The extremely severe local weather in northern Greece on 21 July 1983

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Summary

A description is given of a detailed investigation of the wind storm (*bourini*) which hit the northern and central parts of Greece, particularly the coasts of Macedonia, Thessaly and the city of Thessaloniki, on the evening of 21 July 1983. It is concluded that the wind storm was due to an interaction of local and synoptic-scale meteorological factors.

1. Introduction

One of the most serious problems facing Meteorological Services is the precise forecasting, in space and time, of severe local weather phenomena. This problem has not yet been solved despite recent technological and scientific progress and the effort which has gone into improving the observation, diagnosis and prediction of mesoscale weather systems.

Diagnostic studies are an effective way of understanding the physical and dynamical processes which affect the occurrence and severity of severe local weather phenomena, though such studies have tended to be made as part of the investigation of the larger-scale atmospheric circulation. There has been an enormous increase in the number of diagnostic studies, and much of this work has been pioneered by Fujita in the USA and Browning in the United Kingdom.

Here consideration is given to the diagnosis of an exceptionally severe wind storm which occurred suddenly in Macedonia (the central part of northern Greece) on the evening of 21 July 1983. The storm mainly affected the coasts of Macedonia and Thessaly where the winds reached 80 kn, though less severe winds stretched from the islands of the northern Aegean to Samos in the south (see Fig. 1). In the vicinity of Thessaloniki the storm was particularly severe and the daily newspapers reported the following loss of life and damage:

- (a) Nine people were drowned along the coast of Thessaly and the gulf of Thessaloniki.
- (b) A large number of fishing boats were damaged.
- (c) Many roofs were destroyed.
- (d) Electrical services were interrupted with the result that many people were trapped in elevators.
- (e) Telephone services were interrupted.

Sudden wind storms associated with thunderstorms which occur on the coast of Greece are called '*bourini*' by Greek sailors (Giles *et al.* 1985). Such winds do not appear often in Greece. Consequently

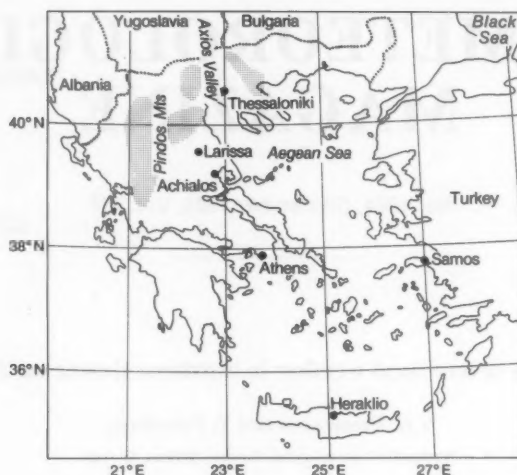


Figure 1. Places and geographical features referred to in this study.

this storm was considered to be a phenomenon of great meteorological importance, the accurate diagnosis of which would contribute towards a better understanding of the physical and dynamical processes which produced a storm of such rare strength.

The diagnostic study described here was based on the following data:

- (a) Surface and upper-air observations in the area 30°N–65°N, 20°W–40°E from the Global Telecommunication System.
- (b) All the observations from the synoptic, aeronautic and climatological stations in Greece.
- (c) The autographic records (pressure, moisture and temperature) from eight synoptic stations.
- (d) Imagery from the NOAA-6 and NOAA-8 satellites.
- (e) Relative geostrophic vorticity and its advection calculated from the ECMWF initialized analyses.

It is impossible to describe all the material studied in this investigation; however, a brief account of the main features is given.

2. Synoptic-scale evolution

2.1 Synoptic situation

At 0000 GMT on 21 July 1983 a ridge dominated the upper-air flow over the central parts of the Mediterranean and north Africa, while central Europe was dominated by a deep low (Fig. 2(a)). South-west of this low there was a region of strong north-westerly flow with cyclonic curvature. In the vicinity of the maximum winds there was a well formed trough. Also there was an associated baroclinic zone at all levels above 700 hPa, though below this level the flow was from the north-west without there appearing to be a trough in either the height or thermal fields. East of the Alps there was a slow-moving cold front (Fig. 2(b)). As it moved southwards there was a rise in pressure behind the front and a ridge of high pressure formed. In the vicinity of the cold front sporadic thunderstorms appeared; these were mainly ahead of the ridge.

Twelve hours later at 1200 GMT the thermal trough at 300 hPa had strengthened while further north a cold pool had formed (Fig. 3(a)). At this time Greece lay in the south-western part of a diffluent trough

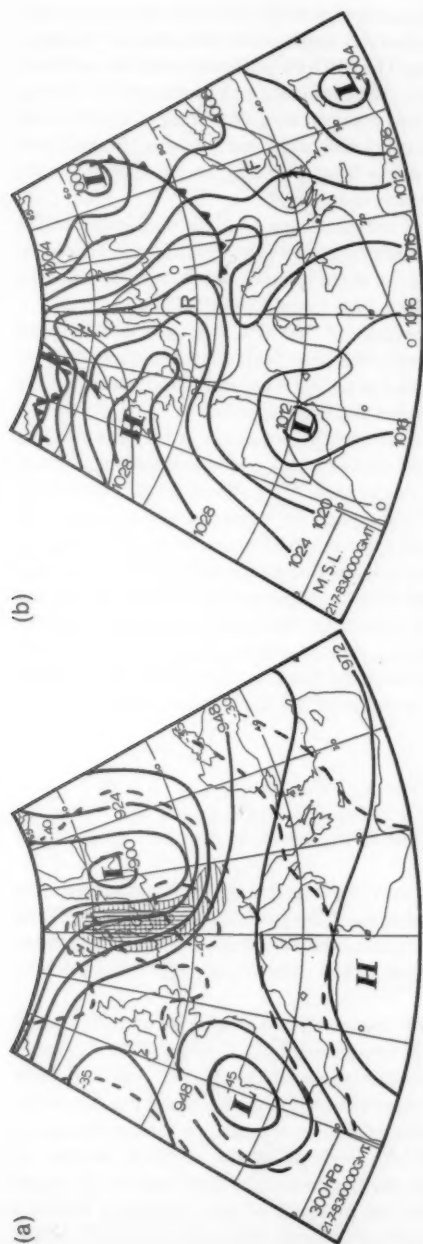


Figure 2. Subjective analyses at 0000 GMT on 21 July 1983. (a) 300 hPa surface: continuous thick lines are contours (dam) and dashed lines are isotherms ($^{\circ}\text{C}$); wind speed ranges 60-80 kn, 80-100 kn and 100-120 kn are indicated by horizontal, vertical and cross hatching respectively. (b) Surface pressure: thick lines are mean-sea-level isobars (hPa) and thin lines are isallobars (hPa per 3 hours); R and F indicate centres of rising and falling pressure.

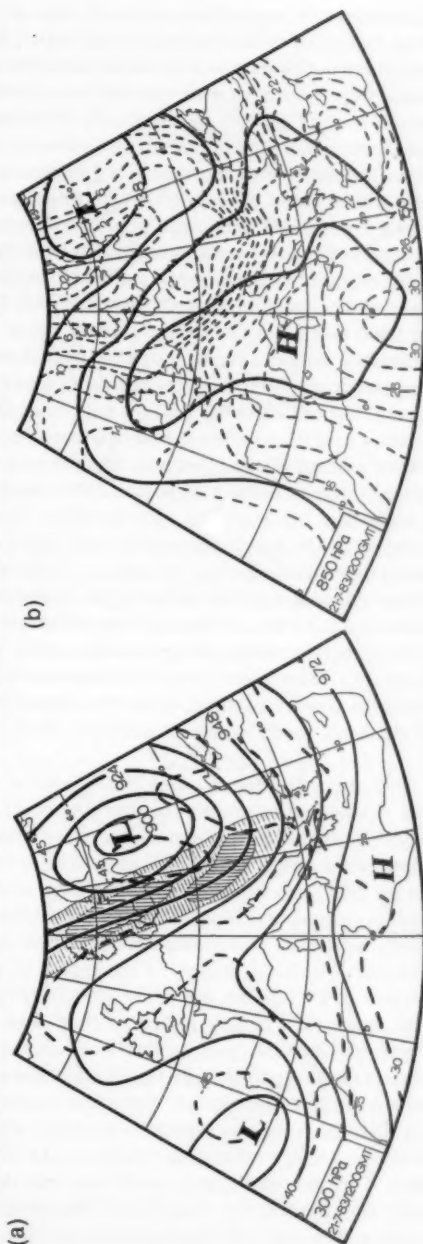


Figure 3. Subjective analyses at 1200 GMT on 21 July 1983 for (a) 300 hPa surface and (b) 850 hPa surface (notation as in Fig. 2(a)).

with strong north-westerlies in the north-west of Greece. Also note that in the Thessaloniki region there was an extension of the thermal trough which showed a relatively small-scale outbreak in the upper troposphere — this increased the static instability in the area. The 850 hPa isotherms over the northern Balkans were orientated west-east and were closely packed — thus indicating the presence of a strong low-level front (Fig. 3(b)). In the vicinity of the cold front it was overcast with a covering of middle-level cloud. However, there were significant amounts of cumuliform clouds and some showers, though there were no thunderstorms reported. The temperatures ahead of the front were well above normal for the season while behind the cold front the temperatures were lower than usual.

As the front accelerated and swept over Greece (Fig. 4) in the afternoon of 21 July, thunderstorms were reported by some stations behind the front though the winds remained at less than 25 kn. There was nothing reported by the synoptic stations to indicate the severity of the phenomena that occurred in the vicinity of Thessaloniki between 1400 and 1800 GMT (1700 to 2100 Local Civilian Time).

At 0000 GMT on 22 July the flow at upper levels, especially at 300 hPa, had still not changed significantly, though a small trough had passed over northern Greece (Fig. 5(a)). At the surface the front was situated over Turkey and the central Aegean (Fig. 5(b)). In Turkey showers and thunderstorms were observed, but in Greece the shallow cold front did not produce any precipitation.

Shallow cold fronts often appear in Greece during the summer months, especially in July and August, and their passage is associated with the commencement of the etesian winds — the well known summer north-easterlies (Constantacopoulos 1959, Metaxas 1971, Prezerakos 1978). These fronts come from the north and are modified over northern Greece. The subtropical jet stream which controls the circulation in the lower stratosphere and upper troposphere (above 500 hPa) in the region is usually situated over Greece during the summer. Thus when a front reaches Greece the subtropical jet stream prevents the cold air from advecting southwards above 500 hPa. In consequence there is no upward extension of the front, and the cold advection and the front are limited to the lower troposphere with the prevalence of descending synoptic-scale motion. Because of this, rainfall and thunderstorms occur only in northern Greece where there is still some ascent associated with the front. In the central and southern parts of the Greek mainland, where the upward extension of the front has been limited, only relatively cold northerly winds appear (Prezerakos 1978).

2.2 *Synoptic-scale factors which contributed to the occurrence of the storm*

The dominant feature on the morning of 21 July 1983 was the slow-moving cold front over the northern Balkans with an associated strong baroclinic zone in the lower troposphere (the intense packing of the 850 hPa isotherms (Fig. 3(b)) is remarkable).

As the cold front strengthened and moved southwards, a vorticity maximum which was apparent in the upper troposphere must also have contributed to the subsequent developments. At 1200 GMT the vorticity maximum was situated north of Greece causing positive relative vorticity advection towards the northern Balkans, mainly in the region of the cold front, while over Greece there was positive advection at 500 hPa but not yet at 300 hPa (Fig. 6).

The upper flow clearly indicated that after 1200 GMT the positive vorticity advection should strengthen in the vicinity of the cold front and move towards Greece mainly in the east of the Pindos, a mountain range on the western Greek mainland and orientated north-south (see Fig. 1). Anyway, while the main positive vorticity advection and main cold front were situated over the western coast of the Black Sea, the front was especially intensive along its southern edge in the eastern Pindos because a secondary vorticity maximum existed at the 500 and 300 hPa levels along the northern borders of Greece. This indicates that a small wave had developed in the north-western flow west of the main trough; the shape of the cloud over Thessaloniki indicates the presence of this secondary vorticity maximum. The cold front appeared to have its greatest movement between 1500 and 2100 GMT. While

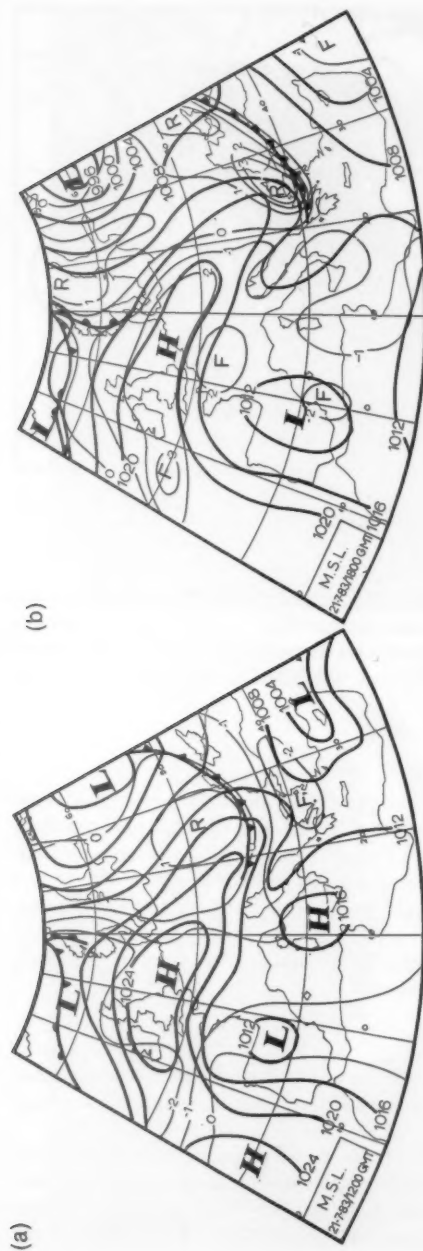


Figure 4. Subjective analyses of surface pressure at (a) 1200 GMT and (b) 1800 GMT on 21 July 1983 (notation as in Fig. 2(b)).

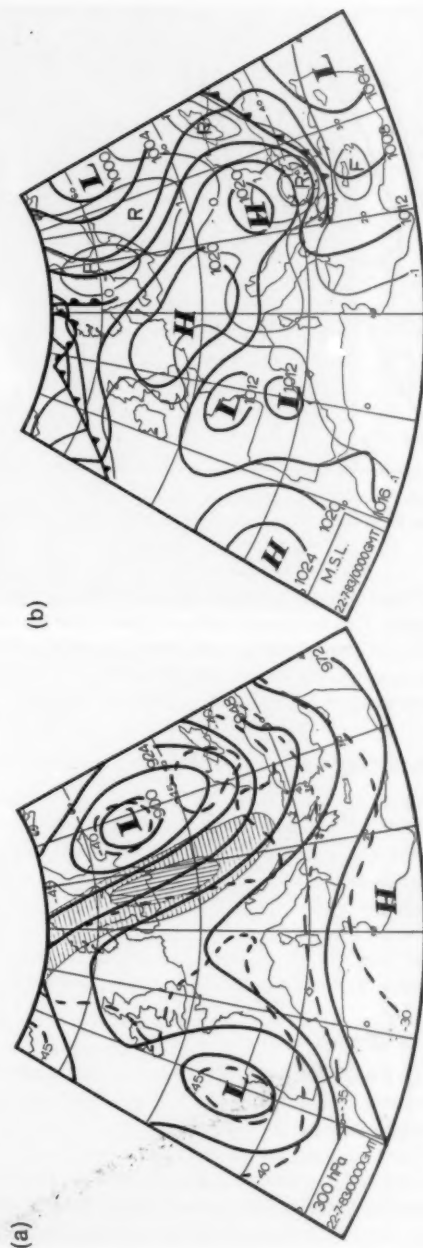


Figure 5. As Fig. 2 but for 0000 GMT on 22 July 1983.

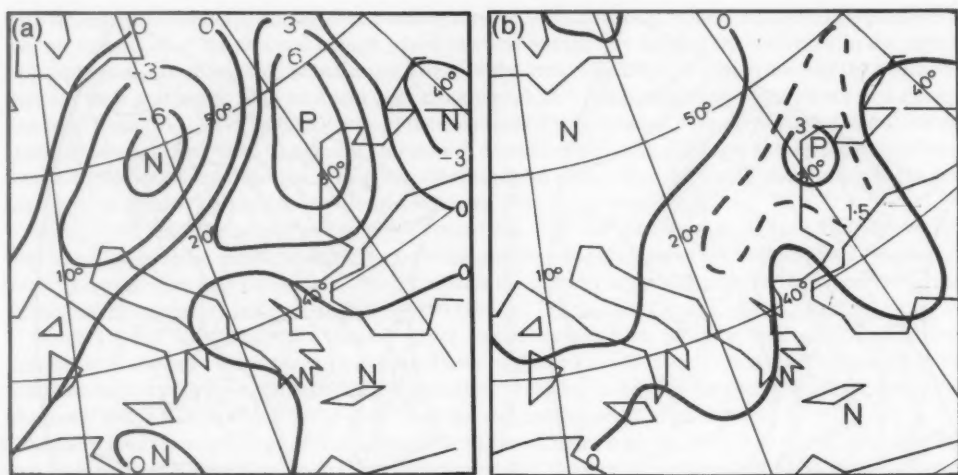


Figure 6. Objective analyses of geostrophic relative vorticity advection (10^{-9} s^{-2}) at (a) 300 hPa and (b) 500 hPa calculated from the ECMWF initialized analyses for 1200 GMT on 21 July 1983. N indicates negative and P positive advection.

the front moved southwards, the secondary vorticity maximum moved towards Turkey across the Aegean. This behaviour is illustrated by the two satellite images given in Fig. 7 and the next one taken at 0120 GMT on 22 July which is not shown here. (Fig. 7(b) also shows that at 1700 GMT the main frontal action appeared to be limited to east of the Pindos and that the Thessaloniki area was on the south-western extremity of the frontal cloud.)

3. Investigation of the problem on the mesoscale

Trying to investigate the wind storm with only the synoptic observations indicates that these observations are unsatisfactory for the study of something which is basically a mesoscale phenomenon. Thus it is necessary to have available precise observations on a smaller space scale and time-scale than the usual synoptic observations. Such observations, however, are lacking in Greece.

In order to overcome this obstacle, a selection of observations has been made which, in a broad sense, can be considered as belonging to a smaller scale than the synoptic one. These observations are mainly those from the aeronautic stations and records from autographic instruments. Also the temperature, humidity and wind profiles can provide small-scale information.

3.1 A detailed study of the weather

Fig. 8 has been prepared from aeronautic observations. It illustrates the situation when the weather phenomena accompanying the *bourini* (strong winds, fall of temperature, rainfall) appeared, and their variation in space and time.

Mikra Airport, situated 15 km from the centre of Thessaloniki, is the most northern of the three stations displayed and it was here that the *bourini* occurred with its greatest strength. At 1450 GMT the surface pressure started to show an anomalous variation and there were 15 kn winds from the north-west. Also the temperature was decreasing and reached its minimum value at 1650 GMT. At this time the

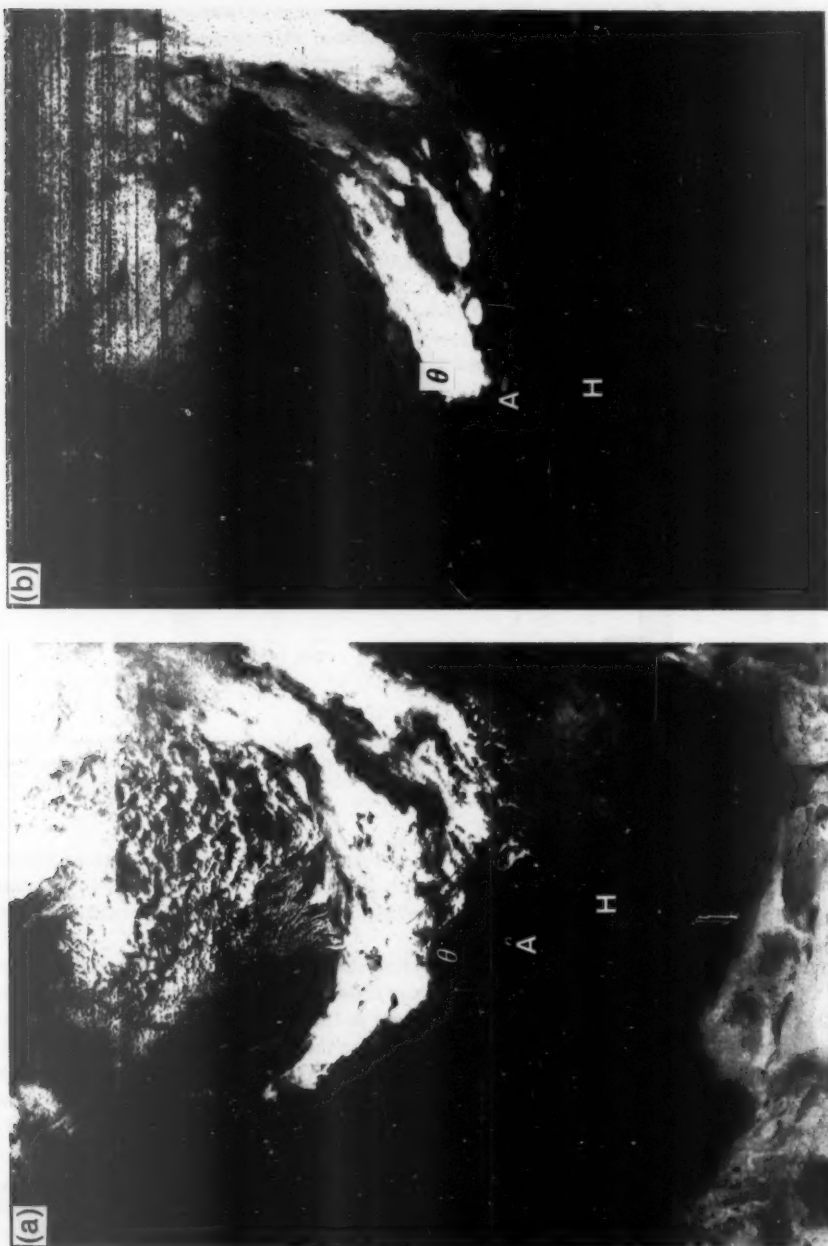


Figure 7. (a) Visible imagery from NOAA-6 received at 1320 GMT on 21 July and (b) infra-red imagery from NOAA-8 received at 1700 GMT on 21 July 1983.
θ — Thessaloniki, A — Athens and H — Heraklio.

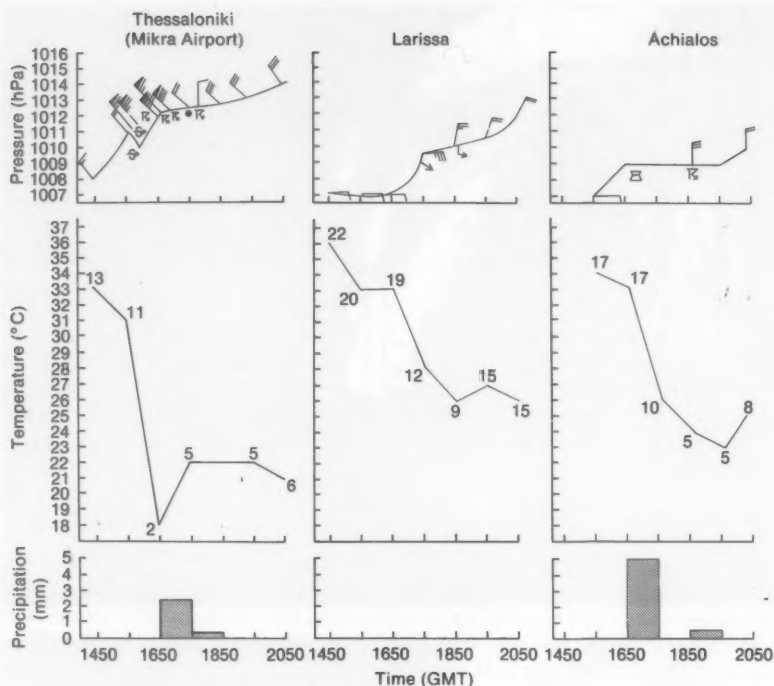


Figure 8. Time section based on aeronautic observations of pressure, wind (kn), temperature, dew-point depression, precipitation and significant weather at three stations in almost a straight line orientated north-south. The numbers plotted on the temperature lines are the dew-point depressions (°C) and the significant weather is indicated by ⚡ for lightning, ☄ for thunderstorm, ☁ for cumulonimbus, ● for rain and ⚙ for wind storm.

relative humidity reached a maximum as a result of the decrease in temperature and commencement of the rain. By 1615 GMT the wind had reached 55 kn with gusts to 65 kn. Around 1700 GMT mature thunderstorms appeared over Thessaloniki accompanied by lightning, strong winds, high humidity and low temperature.

The autographic records show the same as already described but in greater detail as far as time is concerned. One interesting feature that the pressure record showed was that the pressure was decreasing until 1450 GMT and then increased suddenly showing a peak at 1600 GMT. Then the pressure decreased irregularly producing a local minimum at 1630 GMT before there was another sudden increase at 1700 GMT. At this time, according to the aeronautic observations, the thunderstorm was at the zenith of its mature stage. The first increase could have been the pressure jump in advance of an approaching thunderstorm which, in this case, could have been the trigger for the release of the latent instability in the Thessaloniki region (see Tepper 1950). The second increase in the pressure could have been due to the first gusts from the new thunderstorm which developed over Thessaloniki.

From the aeronautic observations and the autographic records it appears that the thunderstorm occurred at Mikra Airport around 1650 GMT when it started raining. The thunderstorm remained until

1850 GMT having its greatest strength during the period 1700 to 1720 GMT. During the same period the rainfall reached its highest rate, the temperature reached its lowest value and the wind speed reached 80 kn (though high speeds occurred from 1615 to 1730 GMT).

The observations from the other stations (see Fig. 1) given in Fig. 8 present almost the same variations in pressure, temperature and humidity, but the variations are neither as sudden or as intense as at Thessaloniki. The significant point is that from the moment when the storm occurred at Thessaloniki the strong winds spread out into the whole region of eastern Thessaly and the northern Aegean Sea.

3.2 Factors influencing the location of the storm

It is interesting to consider why such a strong wind storm developed in the region of Thessaloniki but not further south.

Thunderstorms occur when there is conditional instability and some trigger to release the instability causing the boundary-layer air to ascend to the level of free convection. On 20 July, although there was conditional instability, no thunderstorms appeared because there was no thermal or dynamical trigger.

On 21 July the lower troposphere, in comparison with that of the previous day, was warmed to above 730 hPa whereas there was a sudden cooling of the troposphere above this level — the result was a significant increase in the conditional instability. Thus, on the 1200 GMT tephigram from Mikra Airport (Fig. 9) there is a large area of conditional instability with a convective temperature of 35.7 °C; the maximum temperature which occurred at 1500 GMT was only 34.0 °C. However, at the University

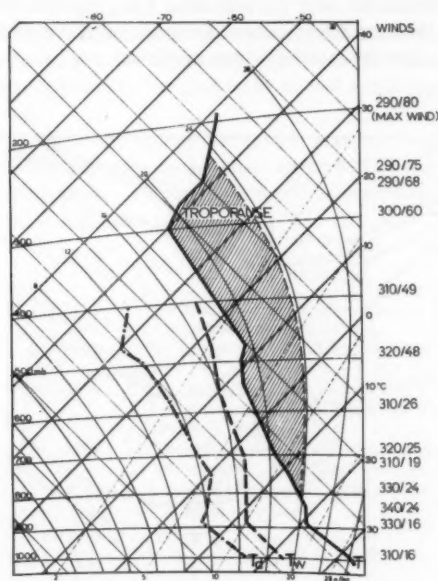


Figure 9. The sounding from Thessaloniki (Mikra Airport) at 1200 GMT on 21 July 1983. The continuous line is the temperature, the dot-dash line the dew-point and the dashed line the wet-bulb temperature. The hatched area is the positive area of the conditional instability. The direction (degrees) and speed (kn) of the winds are given for standard and significant levels.

of Thessaloniki situated in the city, the maximum temperature was 36.3°C at 1300 GMT and the convective temperature was reached at 1130 GMT (assuming that the convective temperature at the university and the airport was the same). Thus for the city of Thessaloniki there was an apparent thermal reason for the release of the conditional instability after 1300 GMT because the convective condensation level almost coincided with the lifting condensation level. However, there was no thermal reason for the release of the instability near the airport.

It is likely that the basic reason for the release of the instability in the Thessaloniki region was the high speed of the approaching cold front and/or a pressure jump which was associated with the thunderstorms accompanying the cold front as it crossed the Balkans towards northern Greece.

Just before the arrival of the cold front, the air in the Axios valley (see Fig. 1) just north-west of Thessaloniki, and further south in the region of the city and the airport, was dry with humidities of about 40% up to 800 hPa. The wedge of cold air behind the front passed through the Axios valley after having released the instability which resulted in new cumulonimbus cells. The thunderstorms occurred over the airport of Thessaloniki at 1700 GMT. At the same time the rain and downdraughts lowered the temperature to 24°C , whereas until 1615 GMT, when the very strong winds started blowing, the air reaching Thessaloniki was warm air which had stagnated in the Axios valley ahead of the cold front. This front, though almost stationary between 0600 and 1200 GMT, moved southwards at 42 kn during the following 9 hours (Fig. 10).

It may be concluded that the combination of the conditional instability in the region of Thessaloniki and the passage of the rapidly moving cold front (which coincided with the period of maximum instability) caused the thunderstorms over Thessaloniki. Also, because of the low humidity, the main feature was the wind rather than the precipitation. The passage of the cold front further south did not result in the same effects because the instability was much less.

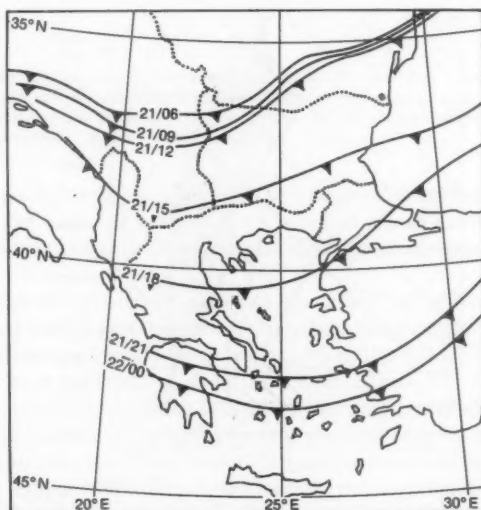


Figure 10. Continuity chart for the position of the cold front from 0600 GMT on 21 July to 0000 GMT on 22 July 1983.

4. Conclusions

This diagnostic study of the *bourini* which occurred in the evening of 21 July 1983 showed that the *bourini* was the result of the interaction of a number of synoptic and local factors. The local factors were responsible for the kind and severity of the weather which accompanied the *bourini*, while synoptic factors were responsible for triggering it.

The main meteorological features on 21 July which emerged from the study are as follows:

- (a) Over the southern Balkans during the morning the air in the lower troposphere was warm and relatively dry. However, the air in the coastal regions was more moist.
- (b) In the region of the Alps and further east there was a strong baroclinic zone in the lower troposphere which began moving southwards just before noon.
- (c) Along the northern edge of the stationary baroclinic zone there was a vorticity maximum moving southwards. Just before noon the maximum arrived above the baroclinic zone and changed it into a strong cold front which moved southwards.
- (d) In comparison with the preceding days, the lower troposphere was warmer and the upper parts colder. This resulted in a great deal of conditional instability.
- (e) In the city of Thessaloniki the maximum temperature was greater than the convective temperature, while in the surrounding countryside it was slightly lower. This meant that a thunderstorm was more likely in Thessaloniki even without the appearance of the cold front.
- (f) The rapidly moving cold front arrived at Thessaloniki just after the time the temperature reached its maximum value. This was responsible for the sudden large ascent in the lower troposphere which forced the air up to the level of free convection and the development of severe thunderstorms.
- (g) As the cold front moved southwards it was accompanied by the usual thunderstorms. The associated gust front could have affected the unstable air which was downstream (Tepper 1950). Thus the *bourini* may have been triggered by the gust front as well as the synoptic-scale vertical motions accompanying the cold front.
- (h) The strong winds were due to the sudden increase in pressure behind the cold front and to the channelling of the Axios valley. However, the gusts up to 80 kn were basically due to the strong downbursts from the thunderstorm. The small amount of precipitation which accompanied the *bourini* was due to the lack of sufficient humidity.

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A comparison of radar and gauge measurements of rainfall over Wales in October 1987

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Summary

Comparisons are made of radar and gauge measurements of rainfall totals over Wales and nearby areas for the period 14 to 19 October 1987. Up to distances of about 130 km from the Cleve Hill radar the radar-measured rainfall amounts are mainly within one half to twice the rainfall measured by co-located gauges, but beyond this distance the radar increasingly underestimates the gauge rainfall.

1. Introduction

The weather of mid-October 1987 in England and Wales was dominated by an area of low pressure to the west of the United Kingdom with active secondary depressions moving in from the south-west.

In central Wales heavy rainfall occurred on the evening of 14 October as a depression moved from the Bay of Biscay to the North Sea. This was followed by further heavy rain in the same area from a depression travelling north-east across central England during the early hours of 16 October. This depression also brought destructive gales to many areas of southern and eastern England. Thundery showers and a near-stationary front to the west of Wales brought yet more rain to this area during the weekend of 17 and 18 October. Flooding occurred in many parts of central Wales following this prolonged period of rainfall (14 to 19 October) with totals greater than 100 mm in many places.

In this paper a comparison of rainfalls for this period over Wales and nearby areas as recorded by gauges and radar is presented.

2. Rainfall observations

2.1 From gauges

Both the climatological network of densely distributed gauges and the synoptic network of sparsely distributed gauges were used in this comparison. The synoptic gauges provide daily 09 to 09 GMT rainfall total observations which are reported in near real-time and are a subset of the climatological daily gauges whose observations are not available until several months after the event.

2.2 From radar

Radar observations are provided by the PARAGON radar data-processing system (May 1988). Those used in this comparison were derived from rainfall intensity data recorded every 5 minutes at the Cleve Hill (see Fig. 1) radar installation in Shropshire. These intensity measurements are integrated to give 09 to 09 GMT rainfall totals averaged over 5 km × 5 km squares. The off-line single-site PARAGON radar data are of a quality similar to the composited on-line intensity data that are available every 15 minutes to weather forecasters and hydrologists.

All UK radar data have two types of correction applied on site in real time (Collier 1986). These are:

- (a) a calibration which varies with rainfall type and locality, optimized within a range of about 100 km from the radar and derived from observations from a few interrogable gauges, and
- (b) a long-range correction, mainly effective beyond 100 km, independent of rainfall type and direction from the radar, which is intended to compensate for the loss of radar sensitivity due to the

beam not detecting rain-producing clouds; this as a result of the curvature of the earth and other effects.

The radar data used here showed the presence of 'spokes' of apparently smaller rainfalls radiating from the position of the radar; these are spurious and are caused by the partial occultation of the radar beam by obstructions. Data suspected of being affected in this way were omitted from the comparison.

3. Comparison of gauge and radar rainfall totals

An objective analysis of rainfall totals from the climatological gauges for the 5-day period 09 GMT on 14 October to 09 GMT on 19 October is shown in Fig. 1. A background field of average annual rainfall was used to improve the detail in some areas, mainly over high ground.

Large totals were recorded in many parts of Wales with a maximum of 268.0 mm at Waen Sychlwch in south Powys. Smaller maxima of 173.5 mm and 164.3 mm were observed at Llydaw Intake in Snowdonia, and at Nevern in the south-west respectively. The totals decreased rapidly to about 50 mm along the Wales-England border (and to about 20 mm in central England).

Fig. 2 shows the corresponding map of 5-day totals derived from radar data from PARAGON. Generally, similar patterns were observed by radar and gauges, for instance the large rainfalls over the high ground in central south Wales, although the maxima in the south-west and over Snowdonia in Fig. 1 are absent from Fig. 2.

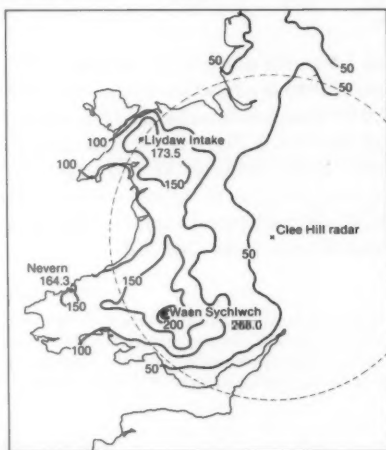


Figure 1. Rainfall field (mm) for the period 09 GMT on 14 October to 09 GMT on 19 October 1987 based on observations from the climatological daily gauge network. Dashed line shows 130 km radius of Clew Hill radar.

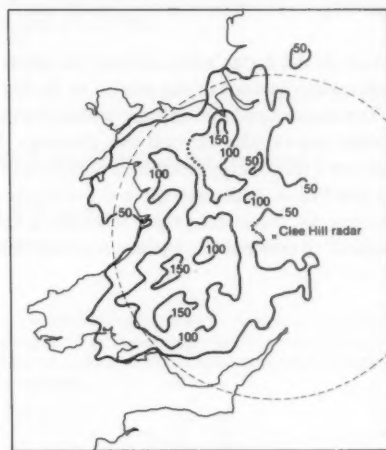


Figure 2. Rainfall field (mm) for the same period as Fig. 1 based on observations from the Clew Hill radar. Dotted lines indicate where data were contaminated by occultation. Dashed line shows 130 km radius of Clew Hill radar.

A more detailed comparison was carried out between co-located synoptic daily gauge and radar rainfalls, both being accumulated automatically during the routine operation of PARAGON. Five-day total radar rainfalls for 5 km \times 5 km squares centred on the gauges were estimated by linear interpolation within the 5-day totals for the surrounding squares. These were used to calculate r/g (the assessment factor AF) at each gauge location (where r and g are the radar and gauge rainfalls respectively). In Fig. 3 the AFs of large rainfall over Wales and surrounding areas are plotted at the gauge locations with smooth contours being drawn by eye. These AFs show values slightly greater than

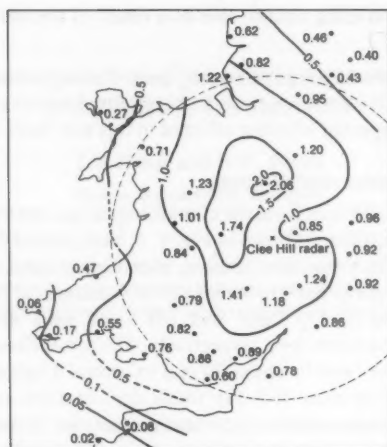


Figure 3. Assessment factor (see text) field for the same period as Fig. 1, determined from synoptic daily gauge observations. Dashed line shows 130 km radius of Cleve Hill radar.

1.0 close to the radar with an area of values greater than 1.5 to the north-west. In general the AFs decrease with distance in any direction. In Fig. 4 the AFs are plotted as a function of distance from Cleve Hill. The majority of the AFs are within the range 0.5 to 2.0 for distances less than 130 km but decrease smoothly and rapidly beyond this distance. The scatter of the AFs in Fig. 4 is not related to rainfall amount and this is supported by a comparison of the location of areas of large AF and large rainfall in Fig. 3 and Fig. 1. Although there is a component of variability in AF, due to the ratios being of area to point rainfalls, this is unlikely to be large for the small rainfall total gradients encountered here and does not appear to conceal the variation of AF with location and distance from Cleve Hill.

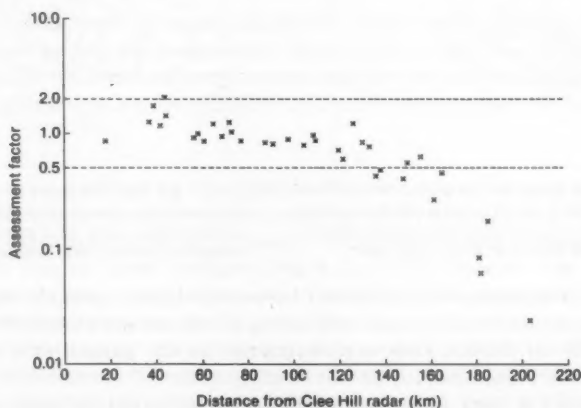


Figure 4. Variation with distance from Cleve Hill radar of assessment factor (see text) for the same period as Fig. 1.

In practice, in England and Wales few areas are more than 130 km from the closest radar (and the number of these areas will diminish as further radars are installed) so the loss of sensitivity is not a problem except for some regions around the edge of the total radar coverage. In PARAGON the daily synoptic gauge observations are used to adjust further the radar data to help remove errors remaining after the on-site calibration and long-range correction are applied. This is done by constructing the spatial field of daily adjustment factor g/r (the inverse of AF) and applying it to the radar daily total field (see May 1988 for an example of this process).

4. Conclusion

Within 100 km from Clee Hill the on-site calibration has been effective in keeping radar totals to within one half to twice the gauge-measured ones. However, it is apparent that the long-range correction applied primarily to improve the 15-minute intensity data for operational use is not effective beyond a range of 130 km for time-integrated data for the rainfall types encountered in this period. This comparison indicates that for such rainfall intensities radar can be used to provide rainfall totals of sufficient accuracy for many operational purposes.

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The impact of analysis differences on a medium-range forecast

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Meteorological Office, Bracknell

Summary

This case-study of a medium-range forecast highlights the sensitivity of numerical model forecasts to the initial conditions and shows how relatively minor analysis differences grow rapidly and progress. The reasons for the differing evolution of the operational Meteorological Office and ECMWF global models are examined using a variety of techniques. Further tests using a revised version of the Meteorological Office analysis scheme are also presented.

1. Introduction

The sensitivity of medium-range forecasts to initial conditions is well known (e.g. Hollingsworth *et al.* 1985). The forecasters in the Central Forecasting Office at Bracknell have access to the products of several numerical weather prediction centres, in addition to those produced by the Meteorological Office model, and are often faced with forecasts showing different evolutions. Clearly the differences can result either from differing initial conditions or from the different model formulations. We have examined in some detail six cases which occurred during the autumn/winter of 1985/86 where the Meteorological Office operational forecasts disagreed significantly with those from ECMWF. Here just one of these case-studies is presented.

The basic technique for comparing operational forecasts from the two centres involves running the ECMWF model from an interpolated Meteorological Office analysis, and running the Meteorological Office model from an interpolated ECMWF analysis. This enables us to ascertain the relative

importance of the different initial conditions and model formulations for a particular case. We have found that in most instances similar forecasts are produced from both models when using the same analysis. Also a transplant technique has been used to isolate a particular geographical area where one analysis might be deficient; this involves the replacement of a portion of one analysis by a portion of another analysis. No consistent difference between the analyses has been found but the technique has enabled us to identify cases which are sensitive to initial conditions, and has proved useful in developing new analysis algorithms.

Throughout the discussion presented here, the forecasts will be identified by analysis and model. Therefore UK/UK indicates a Meteorological Office analysis followed by a forecast from the Meteorological Office model and EC/EC an ECMWF analysis followed by a forecast from the ECMWF model; EC/UK and UK/EC represent the cross comparisons. The forecasts are from a data time of 12 GMT on 8 January 1986. Fields other than 500 mb heights were examined (e.g. surface pressure, 1000–500 thicknesses, 250 mb heights and winds), but the 500 mb fields illustrated here highlight the evolution differences best. Further details about this case* are given in Downton and Bell (1988).

2. The observed and forecast developments

2.1 *The observed developments*

The Meteorological Office analysis showed that at 12 GMT on 8 January 1986, upper vortices were centred over Arctic Canada and just south of Greenland with a strong mid-latitude upper westerly flow extending from the Pacific across the United States to the eastern Atlantic. This was poised to break down a temporary block that had developed over Scandinavia during the previous two days. By midday on the 9th an upper ridge crossed the United Kingdom ahead of the deepening vortex which was still to the south of Greenland. This vortex had moved east 24 hours later to be just to the south of Iceland, with a strong south-westerly flow over the United Kingdom.

The sequence was almost repeated during the next 72 hours (see Fig. 1). The deep upper low to the north of Scotland on the 11th filled and moved east into the Baltic. Another intense development took place as an upper trough, which had been moving east across the United States, moved into the Atlantic on the 12th. By 12 GMT on the 13th this trough had developed into a vortex which was situated to the south of Iceland.

2.2 *Comparison of the forecasts*

A careful comparison of the operational forecasts from the Meteorological Office and ECMWF was made. Figs 2(a) and 2(b) show the 500 mb UK/UK and EC/EC forecasts at day 5, with Fig 1(c) the verification chart. Clearly there are considerable differences between the forecasts. Overall the EC/EC forecast is better than the UK/UK one. The two cross runs, UK/EC and EC/UK forecasts, at day 5 are given at Figs 2(c) and 2(d).

Comparison of all four runs indicates a similarity in each pair of forecasts from the same analysis. Clearly not all the difference between the two operational forecasts can be explained by the analysis differences, but the analysis differences seem to be giving a dominant signal. In order to avoid confusing any model differences with the analysis signal, it is preferable to examine the UK/UK and EC/UK forecasts to try to understand the failure of the operational UK/UK forecast. This procedure may result in a loss of detail from the ECMWF analysis due to interpolation, but the similarity in the forecast in this and other cases indicates that this is not of great importance. The evolution of these forecasts was

* This case was used as an example of the interpretation of numerical forecast products at the Meteorological Office Summer School on 'Diagnosis of Numerical Weather Prediction Products', 6–10 July 1987.

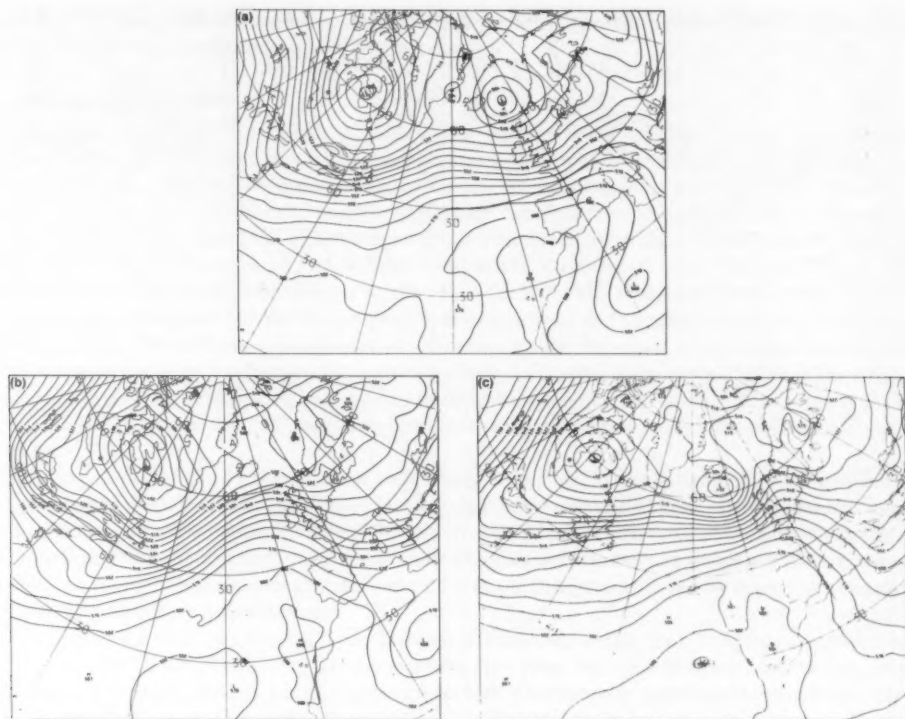


Figure 1. The Meteorological Office analysed 500 mb height (dam) at 12 GMT on (a) 11 January, (b) 12 January and (c) 13 January 1986.

studied carefully to identify the reasons for the large day-5 differences. Substantial differences first became evident by day 3, when the EC/UK forecast had well developed lows just east of Iceland and near the coast of Labrador, with a ridge over the mid Atlantic. A further upstream trough, originating in the east Pacific, had moved through the Rockies ridge to be near 105° W. The corresponding UK/UK forecast showed a much smaller low to the north of Iceland with a very minor ridge in mid Atlantic. During days 4 and 5 developments from the EC/UK forecast were considerably different from the UK/UK forecast with the mid Atlantic ridge amplifying over the United Kingdom thus slowing the eastward movement of the low near Labrador. The trough over North America continued to be moved east at a faster rate than on the UK/UK forecast. At day 5 it is near 30° W as an extension of the 500 mb low (Fig. 2(d)). The speed of this trough appears to be critical in that the slower movement from the UK/UK forecast allowed it to engage warm air that had been moving north-eastwards along the eastern seaboard, thus causing it to deepen with its position near 40° W by day 5 (Fig. 2(a)). We can also see that the low near Iceland and the ridge across central Europe have been moved too quickly eastwards.

Fig. 3 shows the difference between the 500 mb forecasts at day 5 from the UK/UK and EC/UK runs (Fig. 2(a) minus Fig. 2(d)). The negative shaded areas north-east of the United Kingdom (maximum -29 dam) and at 45° W (maximum -20 dam) correspond to the ridge in the EC/UK forecast and the trough in the UK/UK forecast respectively, whilst the positive area over the eastern Atlantic, where a

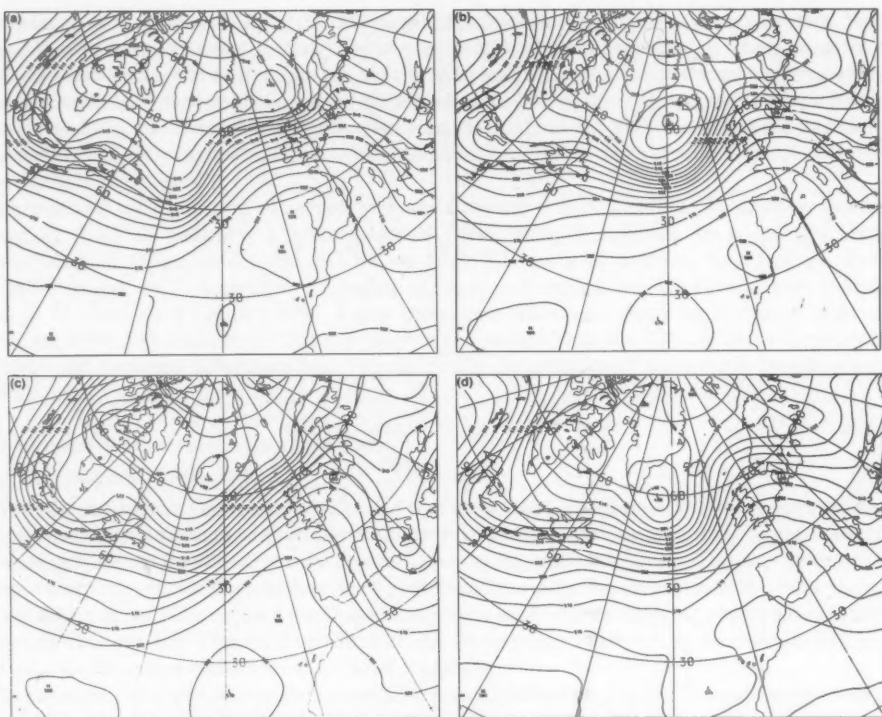


Figure 2. The 5-day forecast from 12 GMT on 8 January 1986 of the 500 mb height (dam) using (a) UK analysis/UK model, (b) EC analysis/EC model, (c) UK analysis/EC model and (d) EC analysis/UK model. For explanation of initials see text.

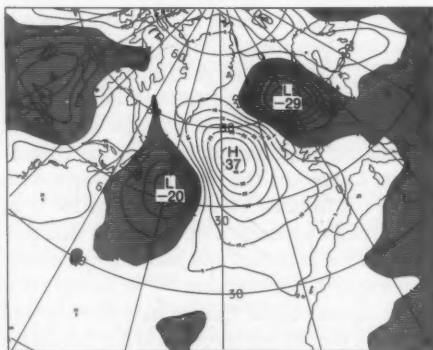


Figure 3. Difference between the 5-day forecasts from 12 GMT on 8 January 1986 of the 500 mb height (dam) from the UK/UK and EC/UK runs (Fig. 2(a) minus Fig. 2(d)). Shaded areas indicate negative values.

maximum difference of 37 dam occurs, shows the difference between the trough in the EC/UK forecast and the ridge in the corresponding UK/UK forecast.

3. A transplant experiment

Comparison of the initial Meteorological Office and ECMWF analyses shows that there are significant differences between them. There are several regions where the 500 mb height differences are greater than 4 dam, but here consideration is given only to the differences over the Pacific Ocean and Alaska. Fig. 4 shows a widespread negative difference over much of this region; this is because the Meteorological Office model has a cold bias of about 1 dam relative to the ECMWF model. There are three areas where differences exceed 4 dam: Alaska, the Californian coast and mid Pacific. The mid-Pacific anomaly results from greater amplitude in the ECMWF analysis of a weak ridge following the major upper trough at 160° W. This anomaly was seen to grow and progress eastwards in the forecast difference fields. The difference progressed at a faster rate than the upper trough-ridge patterns. The initial anomaly resulted in a sharper upper trough which was further forward at 150° W in the EC/UK run at day 1, and this feature can be followed in the difference fields during the following days. The growth of the differences is initially quite slow, but becomes much more rapid after day 3 as the systems progress.

The significance of the Pacific analysis differences in explaining the difference in the operational forecasts can be investigated by carrying out a transplant experiment in which a portion of the ECMWF analysis from the Pacific region (20° N–65° N, 120° W–160° E) is inserted into the Meteorological Office analysis. Both the mass and wind field variables at all levels were transplanted and a smooth transition between the inner transplant area and the remainder of the field was achieved by merging the analyses over a three-grid-length boundary zone.

The effect of the transplant on the 5-day forecast is illustrated in Fig. 5(a). Note that compared with the original UK/UK forecast (Fig. 2(a)) the North Sea ridge becomes sharper and the low to the north-east of Iceland assumes a lesser significance with a centre now appearing to the south-west of Iceland. Also the flow over the mid and west Atlantic is 'flatter' with less pronounced troughs and ridges. The difference chart given in Fig. 5(b) shows a distribution of the low-high-low pattern similar to that in Fig. 3. The values of the negative differences in the Atlantic and northern North Sea are almost identical to those in Fig. 3; however, in the eastern Atlantic the positive difference of 16 dam compared to the 37 dam in Fig. 3 indicates that the transplant was only partly successful in improving the movement and depth of the trough. Several transplants were attempted, but this one produced the greatest improvement over the UK/UK operational forecast.

4. Tests with a revised Meteorological Office analysis scheme

The forecast was rerun using an analysis produced from the analysis correction scheme (Lorenc and Dymelow 1985). This revision to the repeated insertion analysis scheme used at the Meteorological Office is designed to combat some of the deficiencies in the operational scheme. It allows observations to influence the model over a much larger area and no selection is performed so that all observations with a significant weight within the sphere of influence of a model grid point are used. This approach provides a somewhat smoother increment field. The observations are also used in a more timely manner by inserting them into the model during a period around their validity time (particularly important for aircraft reports).

Comparison of the initial analysis fields between the operational analysis and the analysis correction scheme at 500 mb shows the largest differences over the Pacific and Alaska. The 500 mb forecast from the revised analysis scheme at day 5 is shown in Fig. 6(a). A direct comparison of this figure with the

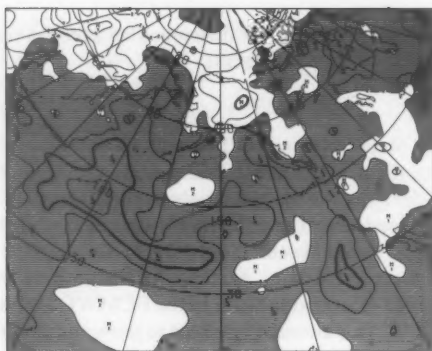


Figure 4. Difference between the Meteorological Office and ECMWF analyses of the 500 mb height (dam) at 12 GMT on 8 January 1986. Shaded areas indicate negative values. Heavy lines enclose areas where differences exceed 4 dam.

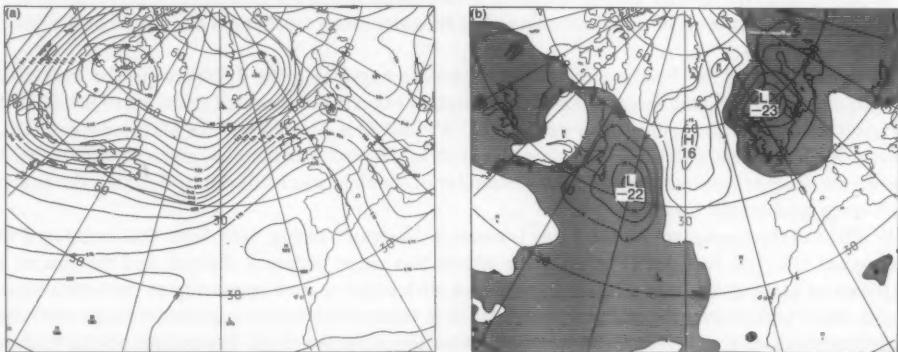


Figure 5. (a) The 5-day forecast from 12 GMT on 8 January 1986 of the 500 mb height (dam) using the Meteorological Office analysis with a portion of the ECMWF analysis (20°N – 65°N , 120°W – 160°E) transplanted into it, and (b) the corresponding difference from the UK/UK forecast given in Fig. 2(a). Shaded areas indicate negative values.

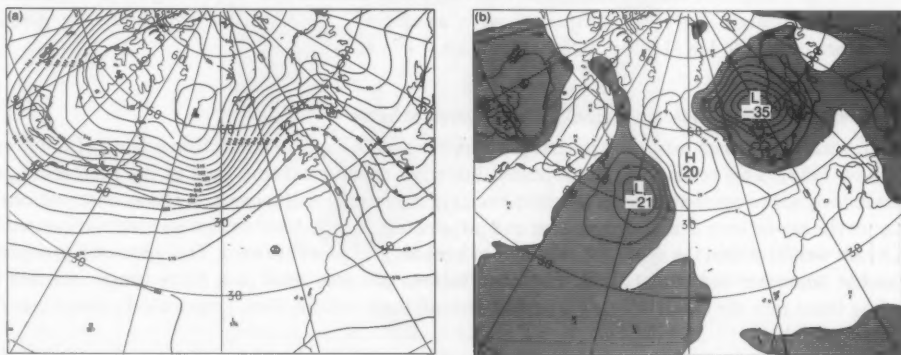


Figure 6. (a) The 5-day forecast from 12 GMT on 8 January 1986 of the 500 mb height (dam) using the analysis correction scheme, and (b) the corresponding difference from the UK/UK forecast given in Fig. 2(a). Shaded areas indicate negative values.

corresponding operational forecast (Fig. 2(a)) and an examination of the verification chart (Fig. 1(c)) show the improvement in the forecast using the analysis correction scheme. See also the differences given in Fig. 6(b) compared to those in Fig. 3.

Investigations of the data used in the analyses suggest that the ECMWF analysis scheme has made more effective use of the sparse volumes of data in the Pacific, particularly the single-level wind data. The improved analysis may be due to the larger sphere of influence given to the observations by the ECMWF scheme as this is a feature which has been incorporated into the analysis correction scheme.

5. Concluding remarks

It has been demonstrated that a poor Meteorological Office analysis was responsible for the poor medium-range forecast from 12 GMT on 8 January 1986. An ECMWF forecast run from this poor Meteorological Office analysis gave an evolution similar to the UK/UK operational forecast.

Difference charts were successful in tracing back the large 5-day difference in the east Atlantic to differences in the analyses in mid Pacific. By means of a transplant technique it has been shown that an analysis error in a relatively small section of the Pacific at upper levels contributed most to the subsequent forecast error. In this instance it seems that the Meteorological Office analysis scheme had difficulty in accepting single-level wind data from aircraft reports.

The new Meteorological Office analysis correction scheme, which is currently nearing operational implementation, provided a better analysis on this occasion, and the forecast from that analysis evolved correctly in most respects to give excellent guidance at day 5 (apart from a small timing error).

References

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| Hollingsworth, A., Lorenc, A.C., Tracton, M.S., Arpe, K., Cats, G., Uppala, S., and Källberg, P. | 1985 | The response of numerical weather prediction systems to FGGE level IIb data. Part I: Analyses. <i>Q J R Meteorol Soc</i> , 111 , 1-66. |
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Joint Centre for Mesoscale Meteorology

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The Joint Centre for Mesoscale Meteorology has recently been brought into existence as a collaborative venture between the Department of Meteorology of the University of Reading and the Meteorological Office.

The objective of the Centre is to promote research in mesoscale meteorology, in order to increase basic scientific understanding of, and improve the skill of forecasting mesoscale weather systems. This will be achieved by developing a focused research programme for the Centre with a balance of observation, modelling, and theory, and by fostering collaboration nationally and internationally.

Much of the significant weather within synoptic-scale systems is organized on the mesoscale; examples include rapidly developing cyclones, frontal phenomena, squall lines, mesoscale convective systems, cold-air vortices, polar lows and local orographic effects. As a consequence of their scale, mesoscale systems are not only inadequately observed by the present operational synoptic network but also poorly resolved by routine weather prediction models. World-wide developments in observational and computer technology will enable mesoscale weather systems to be better resolved leading to progress on their understanding and prediction.

The establishment of the Centre follows the recent example of collaboration in mesoscale meteorology — the Mesoscale Frontal Dynamics Project (MFDP); see Clough 1987*. That project arose from a desire to pool resources and expertise in the universities and the Meteorological Office to study a mesoscale phenomenon of both theoretical and practical interest. Active cold fronts were chosen for the variety of mesoscale structure they exhibit and for the important forecasting problem they represent. At the core of the planning of the MFDP were the mesoscale groups at the University of Reading and in the Meteorological Office. The project includes an important French contribution with a smaller German involvement. The field phase of the MFDP took place from October 1987 to January 1988 and the data look to be of the highest quality. It should be emphasized that such mesoscale data sets will take on a growing importance as numerical weather prediction model resolution increases. It is with the renewed realization engendered in the MFDP that the United Kingdom possesses considerable expertise in basic theory, modelling, and observations of mesoscale weather systems that the Centre was established.

The Centre is composed of three groups: the mesoscale dynamics group of the Department of Meteorology specializing in basic mesoscale research, the mesoscale group of the Cloud Physics Branch (Met O 15) of the Meteorological Office specializing in observations and diagnostics which is located in the Department of Meteorology, and a group in the Forecasting Research Branch specializing in mesoscale dynamics and forecast models which is located at Meteorological Office Headquarters, Bracknell. The move of the Met O 15 group to the university has involved four scientists occupying rooms in the Department of Meteorology. A direct computer link to Bracknell is being used by this group together with graphics, line printer, and PC facilities.

The participating groups in the Centre will be able to draw on a wide range of key research facilities. These include observational data from, for example, radar, satellites, meteorological research aircraft, and radiosoundings. Also, advanced numerical models are available using computers such as the Amdahl at Reading, the Cray-1S at London, the Cray-XMP machines at the Atlas Laboratory and at ECMWF, and the ETA 10 at the Meteorological Office.

A steering group determines the direction and monitors the progress of the Centre. This is currently composed of Dr K.A. Browning, Dr P.W. White and Dr P.R. Jonas from the Meteorological Office, and Professor R.P. Pearce, Professor B.J. Hoskins and Dr A.J. Thorpe from the Department of Meteorology. Further details of the organization and *raison d'être* of the Centre can be found in *Report No. 1* available from the address at the end of this article. The research which forms the Centre's activities is determined by the component groups and forms the basis of the Joint Research Programme of the Centre. This programme is agreed by the participating groups and published on an annual basis; see *Report No. 2* for 1988. The role of the Centre's Co-ordinator, Dr A.J. Thorpe, is to co-ordinate those efforts of individual scientists and groups where these contribute to the Centre's research programme and to foster progress by organizing national and international meetings.

Much of the first year's work of the Centre will involve the MFDP and in particular the analysis and diagnosis of the data in the light of the specific scientific hypotheses set out in the Project's plans. This

* Clough, S.A.: The mesoscale frontal dynamics project, *Meteorol Mag*, 116, 1987, 32-42.

will also involve using forecast and research models to simulate the observed frontal dynamics. The key issues include the dynamics of rainbands, the low-level jet, frontal collapse, frontal waves, upper tropospheric forcing, and the role of diabatic forcing by microphysical processes.

Plans for the future involve research requiring the development of new observational programmes and modelling efforts. Instrument developments, on a time-scale of about 5 years, which are likely to have an important impact on the work of the Centre include: the possible use of an advanced airborne Doppler radar capable of mapping mesoscale and convective-scale fields of motion over large areas, the development of surface-based remote profilers, the availability of Doppler data from some ground-based radars, the provision of high-resolution data from commercial aircraft in the Heathrow area, and the availability of improved sounding products from satellites. Future model developments include greater resolution and larger domain in the mesoscale model, use of non-hydrostatic research models using a variety of vertical coordinates, and exploitation of semi-geostrophic models in finite-difference and geometric-type formulations. The Centre will play an important role in the IAMAP 89 meeting to be held in Reading in August 1989. As well as presenting papers on the scientific results of the MFDP in the symposium on 'Mesoscale processes in extratropical cyclones', a workshop is being planned on the needs and opportunities for observational studies and numerical prediction models of mesoscale weather systems.

Enquiries concerning any aspect of the Centre's activities should be directed to Dr A.J. Thorpe, Joint Centre for Mesoscale Meteorology, Department of Meteorology, University of Reading, 2 Earley Gate, Whiteknights, P O Box 239, Reading RG6 2AU.

Notes and news

Retirement of Mr D.E. Jones

Mr D.E. Jones, MSc, DIC, ARCS, Assistant Director (Synoptic Climatology) retired from the Meteorological Office on 15 July. During a career of nearly 34 years he was involved in a wide range of work in the Office which included research, training, and forecasting at home and overseas.

David Jones was born in 1928 at Dowlais in Glamorgan. One consequence of his move to London (where he spent most of his childhood) about 5 years later was that he left his Welsh accent behind in his homeland, though his true origins are betrayed not just by his name but also by his active love for singing and his ability to become the life and soul of any party.

In 1946 he went up to Imperial College to read mathematics and graduated with a first class honours degree after only 2 years. College regulations demanded that he stay on an extra year and so, as he already had an interest in the weather, he attended courses in the Department of Meteorology which at that time was headed by Professor Sir David Brunt. He was duly awarded an MSc and a DIC at the end of the year. His academic abilities were recognized by an invitation by the Department to stay on for a further 2 years to do research under P.A. Sheppard. This must have been an exciting period to be a student at Imperial College. Rapid advances were being made in the science of meteorology and the Department was expanding with a new influx of enthusiastic young staff; E.T. Eady, F.H. Ludlam, B.J. Mason and R.S. Scorer all joined the Department during these early post-war years.

National Service was, of course, obligatory and David decided that the only way to stay in meteorology was to take a short service commission in the Royal Navy as an instructor lieutenant. It appears that his sea-legs were not unduly tested during his time in the Navy as his 'full sea-time was crossing the Gosport ferry in uniform'. After 6 months at Kete, Pembrokeshire, he spent 2½ years forecasting for RNVR training squadrons at the Royal Naval Air Station, Bramcote where Seafires

(Naval adaptations of Spitfires) were being flown from grass runways. It was during this period that he and Olive were married and their first son was born.

David joined the Meteorological Office in 1954. There were only four people on the Scientific Officers' course at the Training School at Stanmore that year; David is the only one who has remained in the Office until retirement. He didn't do the usual forecasting rounds after the course because of his Navy experience but instead was posted to what was then the Short-range Forecasting Research Branch. Later he helped with the development of the Sawyer-Bushby model and participated in trips to Manchester with Fred Bushby, Mavis Hinds, Janet Portnall and others to use the Ferranti Mark I computer (the joys of these trips have been fully documented by Mavis Hinds, together with a photograph of a youthful, broadly smiling David Jones at the controls of the computer*). In 1960 (after 2 years as an upper-air forecaster at Dunstable) he began a project in the Dynamical Research Branch to develop a model with an explicit tropopause level, and 3 years later he was promoted to Principal Scientific Officer.

In 1966 David successfully volunteered for a posting to Cyprus. One of his earliest tasks was to drive in a stake at the site chosen for the radar for the new radiosonde station to be established at Episkopi (the station was officially opened 3 years later, 1 week after David had left). He closed the station at Akrotiri, where the runway was cracking up, but otherwise his time in Cyprus was uneventful. It was a quiet period, politically, and the only moments of tension occurred when General Grivas returned and it was seriously thought that the Turkish forces would invade the island.

When David was asked at the end of his tour for his views on the future direction of his career, he stated that he didn't want to be a Senior Forecaster, to do research in objective analysis or to do long-range weather forecasting. The Postings Board, in its inscrutable wisdom, immediately posted him to the Central Forecasting Office to be a Senior Forecaster and, 2 years later, to the Forecasting Research Branch (Met O 11) to do research in objective analysis. David was given the task of developing an analysis scheme suitable for use in real-time tropical numerical forecasting during GATE (the GARP Atlantic Tropical Experiment) in 1974. Several novel problems were overcome, including those due to weak geostrophy and the need to analyse both geopotentials and winds. Not least of the difficulties was the impossibility, in the absence of the observational database, of testing the system adequately beforehand.

Promotion to Senior Principal Scientific Officer came shortly after a posting to the Meteorological Office College at Shinfield Park in 1974. There David undertook the task of completely revamping the Scientific Officers' course, especially the dynamics lectures which had remained largely unchanged for nearly a decade. In 1976 there was a move to become Head of Central Forecasting. David was the first occupant of this post with such widespread experience in numerical weather prediction. Even though model guidance had been used for over a decade, there were still ingrained attitudes to change. Long-standing mutual distrust between the Central Forecasting Branch and Met O 11 disappeared and resources were pooled to develop and implement the 15-level model. David was also responsible for redesigning the North Sea shipping forecast areas, including the naming of two new areas North Utsire and South Utsire (these were introduced operationally in the early 1980s).

In October 1980 David was invited to visit China with Sir John Mason, Professor J.T. Houghton and Professor J.L. Monteith. This was one of the earliest foreign scientific parties to go to the country after the death of Mao Tse Tung (they were referred to by some as the Gang of Four). David gave lectures on numerical weather prediction and operational forecasting and visited several scientific institutes in Beijing, Nanjing and Shanghai. In a display of exceptional thoroughness, David learnt enough Chinese to give several short speeches, something that greatly impressed both his hosts and his colleagues.

* Hinds, M.K.; Computer story, *Meteorol Mag*, 110, 1981, 69-81.

David's last posting, in 1981, was to become Head of the Synoptic Climatology Branch, responsible for long-range forecasting. Morale was at a low ebb in the Branch; for many years long-range forecasts had been oversold and it was felt by some that their lack of success was being viewed publicly as representative of the Office as a whole. The Branch became the first victim of the 'Thatcher cuts' in a well publicized decision to discontinue issuing long-range forecasts and to reduce its strength by seven posts. The period also coincided with the retirement of many of the 'old guard' and an influx of younger scientists. It was decided to continue long-range forecasting as a research exercise but to replace the 20 or so manpower-consuming forecasting methods by three highly computerized statistical techniques. Much greater emphasis was placed on research into the physical causes of climate fluctuations on time-scales from months to a few years and on the detection of climate change from quality-controlled observational databases. Long-range forecasting was considered from a world-wide perspective, and global numerical models were employed both for research and for experimental predictions. The success of the Branch over the last 7 years under David's leadership can be judged from the high international regard held for its research work and from its change from the Branch most people would like to avoid to one of the most popular choices for new-entrant Scientific Officers.

Both David and Olive have entered very fully into the social life of the Office despite having to bring up their now adult family of two sons and two daughters. David was Chairman of the Horticultural Society for 9 years and on several occasions Olive had to be on 'stand by' for the prize giving at the spring and autumn shows in case an invited dignitary failed to show up. David now plans an active retirement teaching English to foreign students. We wish both David and Olive a very happy future and trust that their decision to remain in Bracknell will mean that we will continue to see them on many occasions.

P.W. White

Review

Boundary layer climates, second edition, by T.R. Oke. 153 mm × 234 mm, pp. xxiv + 435, illus. London, New York, Methuen, 1987. Price £39.95 (hardback), £14.95 (paperback).

To be fair to the author of the above book the reviewer must open with a confession of only recently becoming involved in the atmospheric boundary layer. In view of this, it is not surprising that T.R. Oke is only familiar to him as the author of the volume in question.

The emphasis of most standard boundary layer texts appears to be on a rigorous mathematical approach rather than a conceptual or physical treatment. For a student it is the latter which, at least initially, is the most useful. *Boundary layer climates* attempts to fill this large gap.

There are three sections each containing several chapters. The first, 'Atmospheric systems', discusses the basic concepts of the boundary layer and the physics associated with it. 'Natural atmospheric environments' describes in detail the various budgets and balances of energy pertaining to several different types of underlying surface, including the climates associated with animals. The final section, 'Man-modified atmospheric environments', describes the effects, both good and bad, that man has on the climate and also any control he has on the weather.

The book is intended to appeal to two groups of readers. The first are those for whom meteorology is an important factor in their field and who require an introduction to its possible effects and applications. The second are students who require a practical supplement to other more theoretical texts.

Very little about either meteorology or mathematics is assumed and, indeed, little more than a rudimentary knowledge of differential calculus is called upon. However, much of the content is based on physical concepts. So, whilst the book does not contain anything particularly technical, a reasonable grounding in physics is an advantage.

Generally the text flows well. It contains discussions about various extremes of environment that the reader may well be unfamiliar with. This, coupled with lucid and rational explanations, invites further reading and suggests that the book is intended to be read from cover to cover. However, in chapters 3 and 4 of section 2 the author has deliberately followed a set pattern for each climate under consideration. Indeed, this makes for easy intercomparison but not for interesting, continuous reading and has more the approach of a reference book. The chapters are reasonably self-contained and there is very good cross-referencing throughout the book. This adds significantly to the ease of reading and allows the possibility of reading a section or even a chapter in isolation.

The general essence of *Boundary layer climates* is one of practicality. Where possible, actual values are put to otherwise abstract quantities. There is an appendix about methods of observing boundary layer parameters and profiles with some of the mathematics that these require. Also, a welcome addition to the first edition is the inclusion of some meteorological tables and physical constants.

A further supplement to the first edition is an appendix called 'Radiation geometry' with, among other things, a method for predicting the path of the sun, a discussion of shape factors and a section on diffuse radiation. Though very interesting and of some practical use, in the light of the general approach of the book it would appear out of place.

There is a detailed index, a large and useful list of symbols and a glossary which explains new terms (italicized) which are not fully explained in the text. There is a good bibliography, a list of authors and, perhaps more useful for the student, a section-by-section list of suggested further reading. The figures are plentiful and clear. The author often includes 'definition' diagrams which greatly aid the understanding of the text. Also, the figures are usually close to the relevant passage, avoiding constant thumbing back and forth.

As either a reference book or textbook *Boundary layer climates* is definitely written with a reader's wishes in mind. It is clear and well constructed and ably fills a much neglected gap in the literature of boundary layer meteorology and is a recommended purchase for newcomers to the subject and for those concerned with agricultural meteorology.

N. Wood

Books received

The listing of books under this heading does not preclude a review in the Meteorological Magazine at a later date.

Our drowning world, by A. Milne (Bridport, Dorset, Prism Press, 1988. £9.95) contains world-wide 'evidence' to support the author's thesis that approximately two thirds of the land surface of the earth could disappear under melted polar ice-cap water. Reasons why a catastrophe will not be averted are also examined.

Applications of thermal imaging, edited by S.G. Burnay, T.L. Williams and C.H.N. Jones (Bristol, Philadelphia, Adam Hilger, 1988. £45.00) aims to present a comprehensive introductory (only high-school physics required) treatment of the subject. The different areas of this multi-disciplinary subject are covered by relevant experts.

Topics in micrometeorology, edited by B.B. Hicks (Dordrecht, Boston, D. Reidel, 1988. £38.00, Dfl.125.00, US \$69.00) is a *Festschrift* to Dr A.J. ('Arch') Dyer, the distinguished Australian micrometeorologist. It consists of a collection of articles on the subject reprinted from *Boundary-layer meteorology*.

The little ice age, by J.M. Grove (London, New York, Methuen and Co. Ltd, 1988. £85.00) places an extensive body of material relating to Europe in the form of documentary evidence of the history of the glaciers within a global perspective. The book contains large numbers of maps, diagrams and photographs, many not published elsewhere.

Meteorology for seafarers, by R.M. Frampton and P.A. Uttridge (Glasgow, Brown, Son and Ferguson, 1988. £27.50) is a revised version of *Meteorology for seamen* and follows its predecessor in setting out to explain the complexities of the atmosphere to professional seafarers and the general reader alike.

Acta Meteorologica Sinica, edited by Chinese Meteorological Society (Chinese Meteorological Press, 1987. £230.00 (annual subscription for four)) provides a comprehensive coverage of Chinese studies and research on all aspects of atmospheric science. Also contained are reviews and information on symposia, and notes for timely reporting of recent significant findings.

Recent climatic change, edited by S. Gregory (London, New York, Belhaven Press, 1988. £33.00) addresses the scientific issues of the subject by researchers from more than a dozen countries. In the wide-ranging topics are included studies of the specific characteristics in particular regions of the globe.

Synoptic meteorology in China, edited by B. Chenglan (Berlin, Heidelberg, New York, London, Paris, Tokyo, Hong Kong, Springer-Verlag, 1988. DM 128.00) is a summary of the complete meteorological research data of China. Verified methods and rules for weather prediction there are also given.

Tropospheric ozone, edited by I.S.A. Isaksen, (Dordrecht, Boston, Lancaster, Tokyo, D. Reidel, 1988. Dfl 190.00, US \$99.00, £58.00) contains the proceedings of a NATO Advanced Research Workshop. Transcriptions of the many presentations are included.

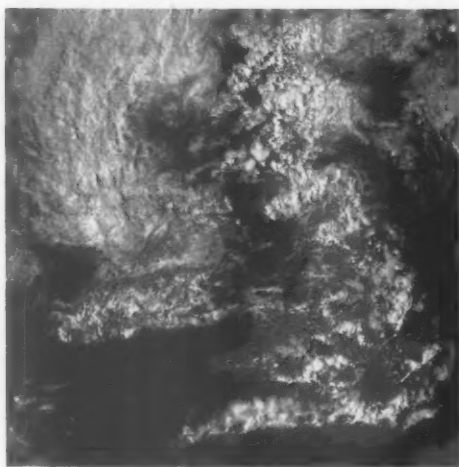
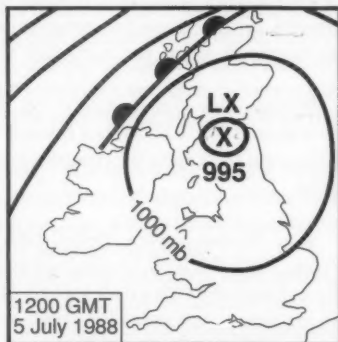
Proceedings of the second TORRO conference on tornadoes and storms, edited by G.T. Meaden and D.M. Elsom (Bradford-on-Avon, Artetech Publishing Company, 1988) is a collection of papers from the conference. A variety of peripheral subjects with an international flavour are presented.

Correction

Meteorological Magazine, May 1988, p. 163, 27th line. Since this article was written the heavy falls of rain at Creebridge and Bargrennan have been amended to 51 mm and 44 mm respectively.

Satellite photographs — 5 July 1988 at 1542 GMT

The NOAA-9 visible and infra-red AVHRR images were taken on a day when an unstable returning polar maritime air mass covered the United Kingdom, in the circulation of a low centred over southern Scotland. In these unstable airstreams, convective cloud and showers often develop in bands dependent on topography and the low-level wind flow. The main feature on the images over southern England is the cloud band extending from Cornwall to Essex. The band originated during the morning within a zone of low-level convergence over the Cornish peninsula and its subsequent growth eastwards was assisted by convergence along sea-breeze fronts. Southern coastal areas remained largely cloud free. However, within the band, heavy showers and thunderstorms occurred (some with hail), causing localized flash flooding. Anvils from the cumulonimbi were blown northwards in the upper southerly flow. Less-marked convective cloud bands can be identified over Wales, north-west England and southern Ireland. Over central and south-west Scotland, near the low centre, numerous slow-moving cumulonimbus cells can be identified.



Visible



Infra-red

Photographs by courtesy of University of Dundee

Meteorological Magazine

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Spelling should conform to the preferred spelling in the *Concise Oxford Dictionary*.

References should be made using the Harvard system (author, date) and full details should be given at the end of the text. If a document referred to is unpublished, details must be given of the library where it may be seen. Documents which are not available to enquirers must not be referred to.

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September 1988

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